ENHANCED LABORATORY HVAC SYSTEM

INTRODUCTION

Since the early 1980's the attention to more energy efficient laboratory designs has been on the rise due to the increase in energy cost and the emergence of the greening umbrella that has been shadowing the different HVAC applications. Since the application of VAV systems entered the laboratory HVAC design in the early 1980's, professional organizations such as ASHRAE, Association of Energy Engineers, Leed, R & D Magazine and Lab 21, have started establishing professional development programs in order to bring innovative designs in the field of laboratory VAV systems. Up to this time, VAV technology had not yet made a drastic change in the laboratory VAV design. The typical laboratory VAV system still has 100% outside air. Installation costs are still high compared to office or commercial building HVAC systems. In addition, energy consumption remains on the rise.

The, propose of this paper is to introduce a new concept in the VAV design of laboratory HVAC systems. This concept is on providing a separate, independent make-up air unit for each floor in lieu of one large centralized make-up air unit for the entire building. (See figure -1-). The purpose of the independent AHU is to provide make-up air for the exhausted air from fume hoods on that floor and to positively pressurize the corridor with a constant flow VAV box with a reheat coil.

In addition, each laboratory space is provided with its own VAV fan coil unit (FCU). The additional cost of this VAV/FCU is offset through the energy savings accomplished by utilizing this system. See figures -2- and -3-.

The concept is not actually new since it has been partially in use at several laboratories in the Natural Science Building at a major U.S. University.

EXAMPLE

- In order to compare the advantages and disadvantages between the conventional lab VAV systems versus the VAV/FCU system with an independent make-up air unit for each floor, a four story laboratory building with 28 fume hoods is selected. For simplicity, each hood exhausts 700 CFM at full open sash and 250 CFM at closed sash, face velocity is 100 FPM at any sash position. Each FCU supply air is 600 CFM maximum and 150 CFM minimum in capacity. There are (7) FCU'S on each floor. Also, each floor is provided with fixed 900 CFM for corridor pressurization, and with a reheat coil and a thermostat. The capacity for each floor make up AHU is 5,100 CFM maximum and 1,950 CFM minimum. Lab space module is 24' long x 12' wide x 8½' high. Total of (28), equal Lab modules.
- How often is the fume hood sash raised to full open position? Per laboratory user's survey conducted by BD&C/RICS in September 2003 (see figure -4-), the actual hood full sash opening per (8) hour day is estimated to be 32.4% which is equivalent to 2.6 hours per 8 hours a day. Therefore, 5.4 hours per 8 hours a day and the rest of the 16 hours of the day, the hood sash is expected to be in the closed position. The exhaust CFM through the hood is a

minimum of 250 CFM, with 450 CFM is returned air from the lab space to the fan coil unit to mix with the 150 CFM from the make-up air unit.

- Estimated cooling thermal energy saved, in BTU per HOUR is:
  BTU/HR = R.A. CFM x (Mixed air temp. - Supply air temp.) x 1.08
  = 450 x (70 - 55) x 1.08
  = <u>7290 BTU/HR</u> (Cooling)
- Estimated heating thermal energy saving by reducing/eliminating the reheat energy through the use of lab space return air:
  BTU/HR = Heated Air CFM x (Supply air temp. - Mixed air temp.) x 1.08
  = 450 x (80 - 68) x 1.08
  = <u>5832 BTU/HR</u> (Heating)

COMPARISONS

The following is a table format that shows the comparison between the conventional VAV lab HVAC system with one central large VAV/AHU, and the proposed (4) small, VAV, make-up air AHUS with one AHU dedicated for each floor, and one VAV/FCU dedicated for each lab. We assume that all other non-lab spaces in the building are served by separate AHUS.

Table -1-

Enhanced Lab VAV/FCU System with (4) Small Make-Up Air AHUS	Conventional Lab VAV System with one large HVAC AHU
1. Four small VAV AHUS one for each floor, with a capacity of 5,100 CFM each maximum and 1,950 CFM each minimum	1. One large VAV AHU for the entire (4) story building is 20,400 CFM, maximum and 7800 CFM minimum.
2. Premium energy saving is accomplished by approximately 68% per 8 hours day since the hood sash is closed with 250 CFM exhaust and lab air is re-circulated back to the FCU in the amount of 450 CFM.	2. Lab air is always exhausted whether hood sash is raised or lowered. Lab air is exhausted through the hood when sash is raised, and the air is exhausted through lab EVAV when sash is lowered with variable CFM depending on lab conditions.
3. Lab space exhaust air is reduced by approximately 68% per 8 hour day.	3. Lab space exhaust air is only reduced when there is a reduction in cooling CFM requirements.
4. Outdoor air is cooled and dehumidified to a dew point drier than the spaces and is delivered directly to the FCUS.	4. Outdoor air dehumidification is limited, unless reheat at VAV boxes is energized.
5. Space requirements for the smaller AHU are 4'W x 8'L x 3'H plus 4'x4' coils pull spaces requirements. The total floor space requirements are $64ft^2$. 64x4= $256ft^2$ total area	5. Space requirements for the one large AHU are 8'W x 24'L x 6 ½'H plus 8' x 8' coil pull spaces requirement. The total floor space requirements are $384ft^2$. total area

6. Smaller AHU weight is approx. 2500 LBS concentrated in one area.	6. Large AHU weight is approx. 11,000 LBS concentrated in one area.
7. Cost of structural supports is approx. $2000 for four units.	7. Cost of structural supports is approx. $12,000.
8. Cost of unit purchase is approx. $6000. 6000x4=$24,000	8. Cost of unit purchase is approx. $60,000.
9. Supply fan motor HP for each unit is 7½ HP. 7 ½ x4=30HP total	9. Supply fan motor HP is 40HP.
10. Cost of DDC system is $7,500 for each unit. 7,500 x 4 = $30,000	10. Cost of DDC system is $35,000 due to size of unit and additional points.
11. Cost of supply ductwork from each of the four AHU'S is $10,000. 10,000x4=$40,000 total. Duct risers are eliminated.	11. Cost of supply ductwork from large AHU is $75,000 due to larger main ducts and duct risers.
12. Piping connections cost to each unit is $5,000. 5,000 x 4 = $20,000	12. Piping connections cost to the large AHU is $24,000.
13. Cost of each 7 ½ HP variable speed drive is $750. 750x4=$3,000	13. Cost of 40HP variable speed drive is $6,000.
14. Estimated maintenance cost for each AHU is $500 per year. 500x4=$2000	14. Estimated maintenance cost for the large AHU is $5,000 per year.
15. Estimated cost of assembling each AHU is $500. $500x4= $2000.	15. Estimated cost of assembling large AHU is $6000.

- Estimated cost per FCU, installed and operating is:

a.) FCU purchase and installation: $750, including a factory mounted and wired VSD.
b.) CHW, HWH and Condensate waste piping: $2,000.
c.) Ductwork connections to FCU and R.A. VAV box: $1,000.
d.) Modify Lab DDC type control to include FCU: $500.
e.) Electrical service to FCU: $300
Total = $4550 cost per VAV/FCU, installed and operational.

- Total systems savings - from table -1-

a.) Item 7, $7,000 - $1,500 = $5,500 savings in supports.
b.) Item 8, $60,000 - $24,000 = $36,000 savings in purchase of units.
c.) Item 9, (10HP x 0.746 x $0.083 per KWH x 8760) ÷ 0.92
= $5896 per year electrical energy savings because of lower motor HP.
d.) Item 10, $35,000 - $30,000 = $5,000 savings in DDC.
e.) Item 11, $60,000 - $30,000 = $30,000 savings in supply ductwork.
f.) Item 12, $24,000 - $20,000 = $4,000 savings in piping connections.
g.) Item 13, $6,000-$3,000 = $3,000 savings in VSDS cost
h.) Item 14, $3,000 - $2,000 = $1,000 savings in maintenance cost.

- From gathering the above installation cost there is a saving of $89,500 from using the small AHU for each floor, and a VAV/FCU for each lab space.

- Floor type VAV/FCUS are used in lieu of ceiling type due to ease of maintenance and noise control.

AN INDEPENDENT STUDY

A major Midwestern U.S. University hired the services of a nationally recognized planning and design consulting firm to provide a comparison for one of its Biological Science Research Building (BSRB) between the conventional Lab VAV systems versus a constant flow four pipe fan coil unit (FCU) system. The summary of the comparisons results for a 30 year period showed the following:

	ONE CENTRAL VAV AHU FOR BUILDING		FCU FOR EACH LAB SPACE	
Year	Annual Savings	Cumulative Savings	Annual Savings	Cumulative Savings
1	$100,000	$100,000	$500,000	$500,000
2	$102,000	$207,000	$510,000	$1,035,000
3	$104,040	$321,390	$520,200	$1,606,950
4	$106,121	$443,580	$530,604	$2,217,902
5	$108,243	$574,003	$541,216	$2,870,013
6	$110,408	$713,111	$552,040	$3,565,554
7	$112,616	$861,383	$563,081	$4,306,913
8	$114,869	$1,019,320	$574,343	$5,096,601
9	$117,166	$1,187,452	$585,830	$5,937,261
10	$119,509	$1,366,334	$597,546	$6,831,670
11	$121,899	$1,556,550	$609,497	$7,782,751
12	$124,337	$1,758,715	$621,687	$8,793,576
13	$126,824	$1,973,475	$634,121	$9,867,375
14	$129,361	$2,201,509	$646,803	$11,007,547
15	$131,948	$2,443,533	$659,739	$12,217,664
16	$134,587	$2,700,296	$672,934	$13,501,481
17	$137,279	$2,972,590	$686,393	$14,862,948
18	$140,024	$3,261,243	$700,121	$16,306,216
19	$142,825	$3,567,130	$714,123	$17,835,650
20	$145,681	$3,891,168	$728,406	$19,455,838
21	$148,595	$4,234,321	$742,974	$21,171,604
22	$151,567	$4,597,603	$757,833	$22,988,017
23	$154,598	$4,982,082	$772,990	$24,910,408
24	$157,690	$5,388,876	$788,450	$26,944,378
25	$160,844	$5,819,163	$804,219	$29,095,816
26	$164,061	$6,274,182	$820,303	$31,370,910
27	$167,342	$6,755,233	$836,709	$33,776,164
28	$170,689	$7,263,683	$853,443	$36,318,416
29	$174,102	$7,800,970	$870,512	$39,004,848
30	$177,584	$8,368,603	$887,922	$41,843,013

The above comparison shows a surprisingly favorable approach in using the FCU system versus the one centralized VAV/AHU system. Comparison analysis is based on 152,440ft^2 labs floor area, 457 FCUS, and1440 tons of cooling.

NCLUSION

In order to perform a satisfactory laboratory HVAC design for your client and an enhancement to the lab VAV system, always seek the idea of several design options, and particularly, if you were not sure of the final costs of these options.

1. Design one system and make it Base Bid, then provide a complete design for the other system and call it "A Deduct Alternate" therefore the Base Bid and the Deduct Alternate should be two different floor plans, sections, schedule detail and specifications. This way, the mechanical contractor can clearly follow the installation of either design.
2. In specifications, create a new section of specifications, and call it "Laboratory HVAC System and Related Controls". Specify that the fume hood controls supplier is to be the laboratory HVAC contractor who will hire the sheet metal contractor as his sub-contractor, however, the full responsibility will still be by the laboratory HVAC contractor. In this section of the specifications include the following responsibilities of the lab HVAC contractor:
    a.) Supervise the installation of the VAV boxes by the sheet metal contractor.
    b.) Furnish the VAV boxes and their related controls.
    c.) Furnish factory insulated supply VAV boxes, including the reheat coil section if any.
    d.) Furnish, install and wire the fume hoods controllers.
    e.) Furnish and install all electrical work related to the lab space HVAC system and may hire the electrical sub-contractor to do this work, but the lab HVAC contractor will still be responsible for it.
    f.) Provide check, test, start, air balancing and water balancing inside each Lab space, including Lab pressurization, testing and confirmation of fume hoods face velocity at different sash heights and in accordance with ASHRAE 110-2005.
    g.) Coordinate work with laboratory DDC contractor to confirm the proper operation of the automatic pressurization of the Lab space.
    h.) Furnish, install and calibrate the Lab pressurization indicating gauges which are normally mounted above the door. Specify that visualization of the lab pressurization indicator is from both sides, corridor and lab.
    i.) Confirm the constant pressurization of the corridor. Coordinate with the project air balancing and water balancing contractor. Air balancing contractor is to perform balancing work outside the laboratory.
3. Try to select a laboratory HVAC contractor who also provides fume hoods exhaust fans. This way, the complete lab system becomes one responsibility.
4. A lab HVAC contractor is to be accompanied by the client's OSHA representative and commissioning agent to provide a label on each hood, signed, and dated by the OSHA industrial hygienist, indicating that hoods meet the fume hood velocity requirements (refer to ASHRAE 110-2005).
5. Include commissioning work as part of the lab HVAC specifications.
6. Where a reheat system is required, design a dedicated boiler system for this purpose, independent of the building winter heating system.

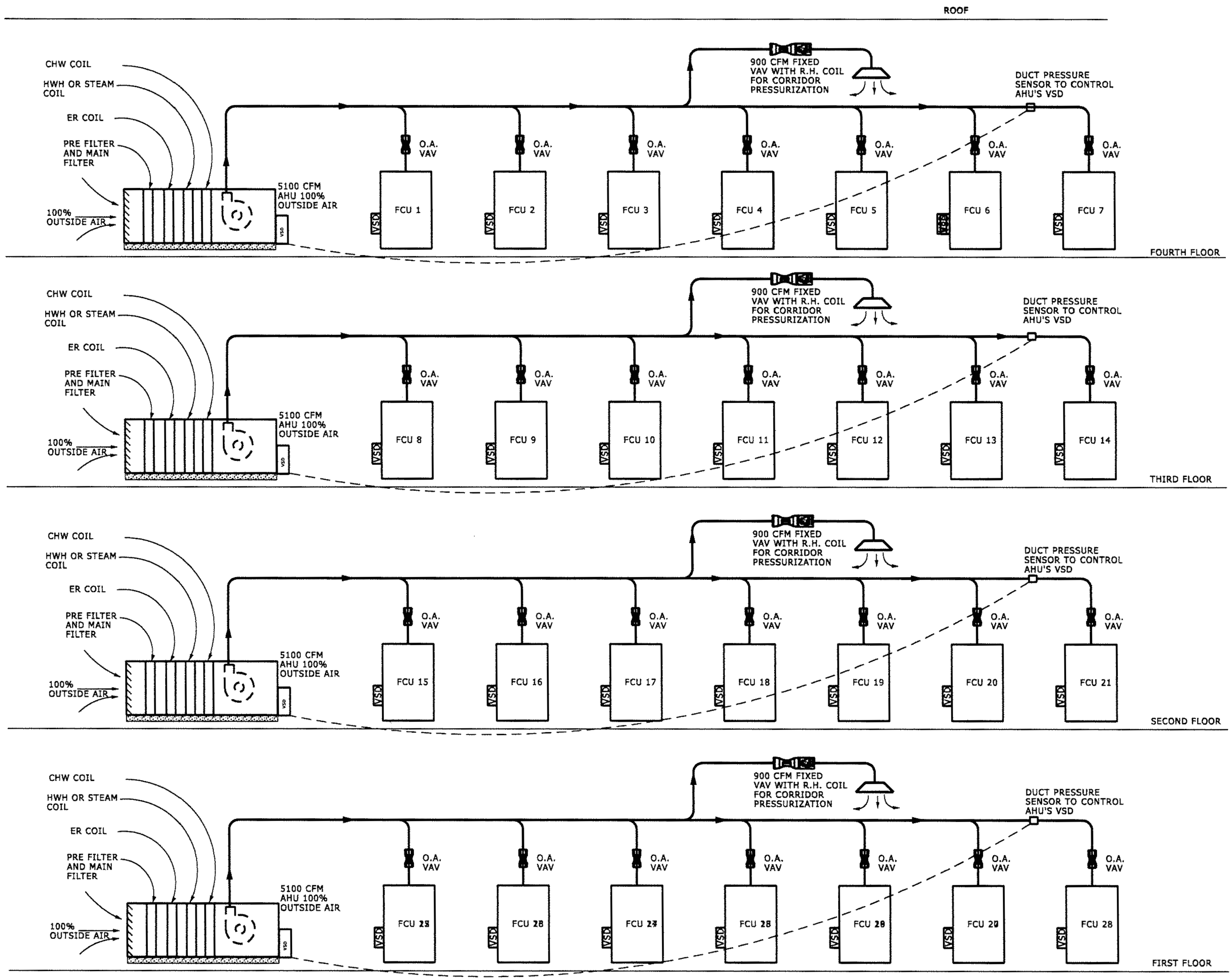

FIGURE - 1 - DIAGRAM OF ONE AHU PER FLOOR SUPPLY DUCTWORK DISTRIBUTION TO FCU

NOTE:

IN COLD CLIMATES, BELOW 40°F. AMBIENT TEMPERATURE A FACE AND BYPASS DAMPER IS REQUIRED ON THE HWH COIL

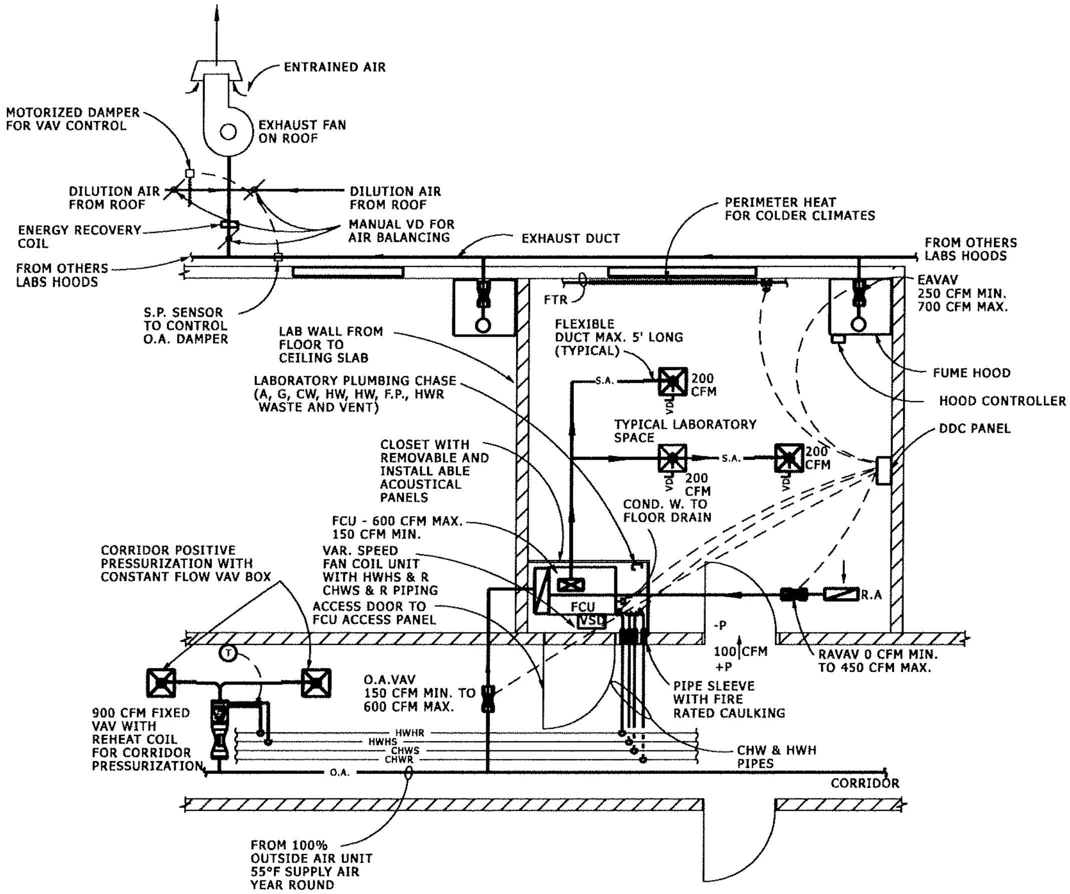

FIGURE - 2- TYPICAL LAB - ONE FCU PER LAB - PLAN VIEW

LEGEND

OAVAV = OUTSIDE AIR VARIABLE AIR VOLUME BOX
RAVAV = RETURN AIR VARIABLE AIR VOLUME BOX
SAVAV = SUPPLY AIR VARIABLE AIR VOLUME BOX
EAVAV = EXHAUST AIR VARIABLE AIR VOLUME BOX

SEQUENCE OF OPERATION (DDC) TYPICAL LAB - ONE FCU PER LAB

FAN COIL UNIT IS ALWAYS ON, HOWEVER ITS FAN SPEED VARIES IN ACCORDANCE WITH HOOD SASH OPENING AND CLOSING, AND IN ACCORDANCE WITH SPACE TEMP. SENSOR SETTINGS.

SPACE PRESSURIZATION

WHEN HOOD SASH IS RAISED, EAVAV OPENS TO ACHIEVE 100 FPM FACE VELOCITY AT HOOD FACE, THROUGH DDC PANEL, IN SEQUENCE OAVAV OPENS AND RAVAV CLOSES. RAVAV CLOSES IN PROPORTIONS TO ALLOW 100 CFM NEGATIVE PRESSURE (-P) IN THE LAB SPACE (ADJUSTABLE).

SPACE TEMPERATURE AND HUMIDITY CONTROL

1. SPACE TEMPERATURE THERMOSTAT INSIDE THE (DDC PANEL) WILL CONTROL SPACE TEMPERATURE BY SEQUENCING HEATING AND COOLING CONTROL VALVES ON THE FCU PIPING, AND BE INDEPENDENT OF HOOD SASH MOVEMENT.

2. WHEN HOOD SASH IS DOWN, AND LAB SPACE REQUIRES TEMPERATURE RISE, SPACE SENSOR INSIDE DDC PANEL, WILL DECREASE FCU FAN RPM THROUGH THE VSD, OPEN RAVAV, CLOSE EAVAV TO MINIMUM. CLOSE OAVAV TO MINIMUM, AND GRADUALLY OPEN HWH VALVE.
WHEN HOOD SASH IS RAISED AND LAB SPACE TEMPERATURE NEEDS TO BE LOWERED SPACE SENSOR, THROUGH DDC, WILL INCREASE FAN RPM THROUGH THE VSD, CLOSE RAVAV, OPEN OAVAV AND OPEN EAVAV.

3. CHW AND HWH RUN YEARROUND.

4. DEHUMIDIFICATION OF THE LAB SPACE CAN BE ACCOMPLISHED THROUGH INSTALLING THE HWH COIL DOWNSTREAM OF CHW COIL. WHEN R.H. SENSOR INSIDE DDC PANEL IN THE ROOM READS, ABOVE IT IS SETTING CHW COIL CONTROL VALVE GRADUALLY OPENS TO DEHUMIDIFY AND HWH COIL CONTROL VALVE GRADUALLY OPENS TO KEEP THE LAB SPACE FROM OVERCOOLING.

5. FOR SPACE HUMIDIFICATION, A HUMIDIFIER MAY BE INSTALLED IN SUPPLY DUCT, AND BE CONTROLLED BY THE DDC PANEL.

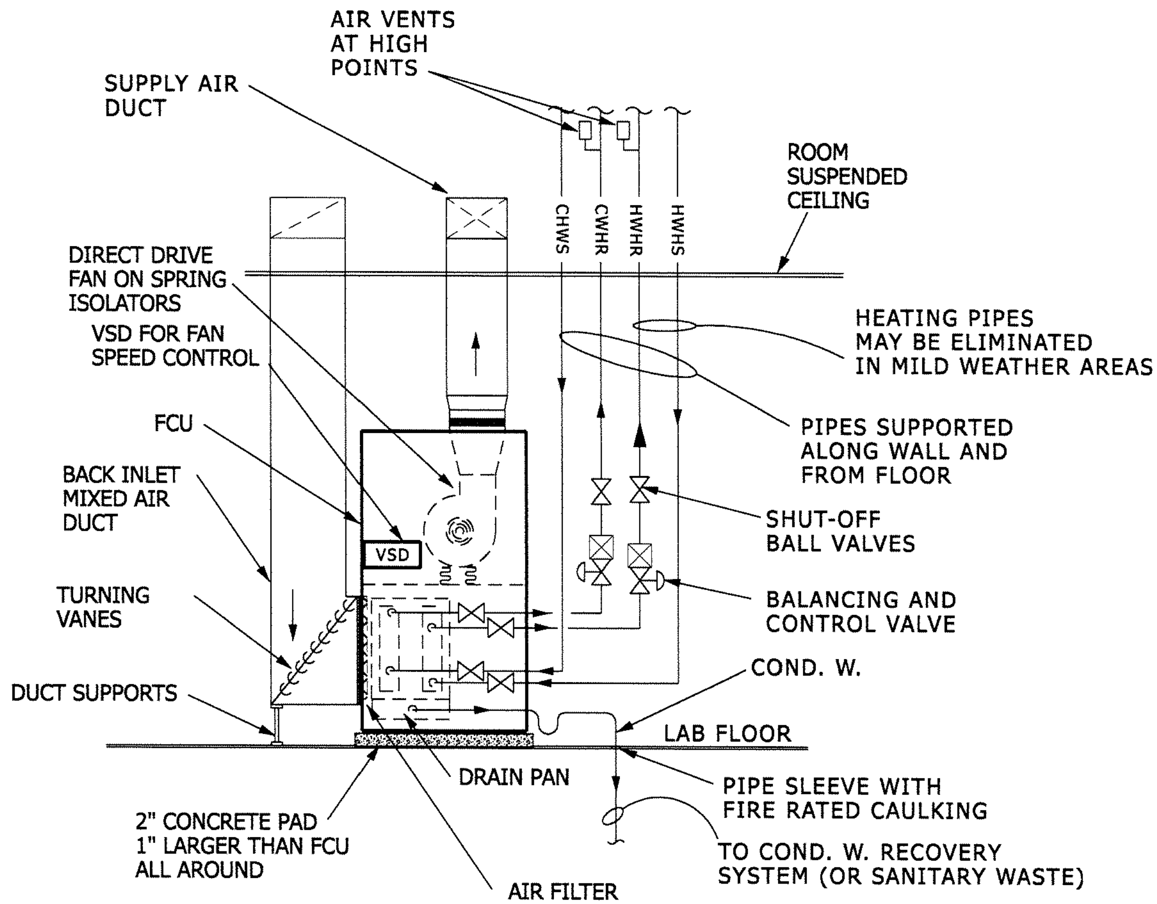

FIGURE - 3 - VAV/FCU ELEVATION VIEW FROM CORRIDOR SIDE

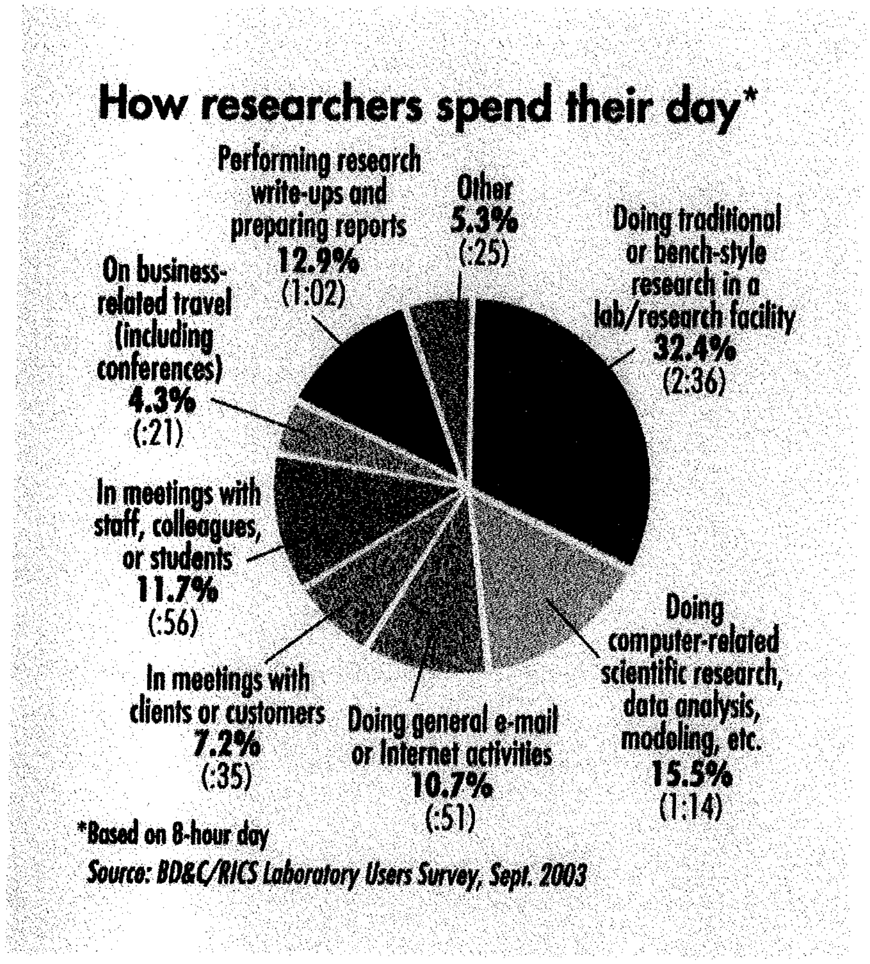
How researchers spend their day*
Performing research write-ups and preparing reports 12.9% (1:02)
Other 5.3% (:25)
Doing traditional or bench-style research in a lab/research facility 32.4% (2:36)
On business-related travel (including conferences) 4.3% (:21)
In meetings with staff, colleagues, or students 11.7% (:56)
Doing computer-related scientific research, data analysis, modeling, etc. 15.5% (1:14)
In meetings with clients or customers 7.2% (:35)
Doing general e-mail or Internet activities 10.7% (:51)
*Based on 8-hour day
Source: BD&C/RICS Laboratory Users Survey, Sept. 2003

Figure -4-

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